



ClearMotion



Contents



Product Overview

Technical Deep Dive

Video Demonstration: Super-Active Ride Control



Constant Tradeoff: Ride vs. Handling

Athletic Handling

Silky Comfort



Two cars in one: Industry pursuit over 30 years, **no solution yet.**

Super-Active ride has been the goal for 30 years

Previous attempts have failed for 4 key reasons

1989: GM
Hydraulics + Ballscrew



Inefficient

1		
Energy	1-15 HP	

1991: Nissan
Centralized Hydraulics



Slow Response, Bulky

2		
Form Factor	50-150 kg	

2005: Bose
Electromagnetics



Too Costly

3		
Cost	\$4k-20k	

1999-now: Daimler
Centralized Hydraulics

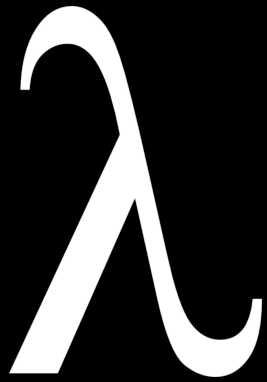


Poor performance

4		
User Experience	Slow Response Time	

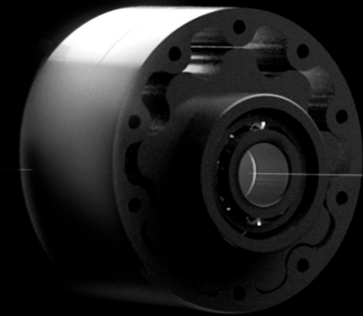
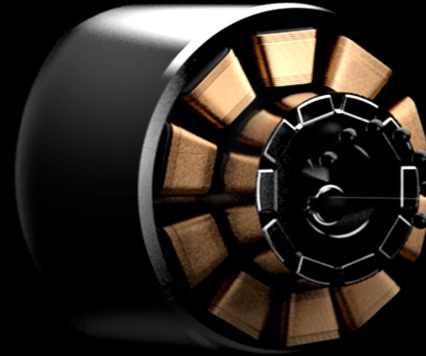
Billions invested to build a commercially-viable active suspension system

How did we do it?



Innovative Software Controls.

30 software engineers
optimizing controls software to
create unparalleled experience
(this is vast majority of our
ongoing innovation)

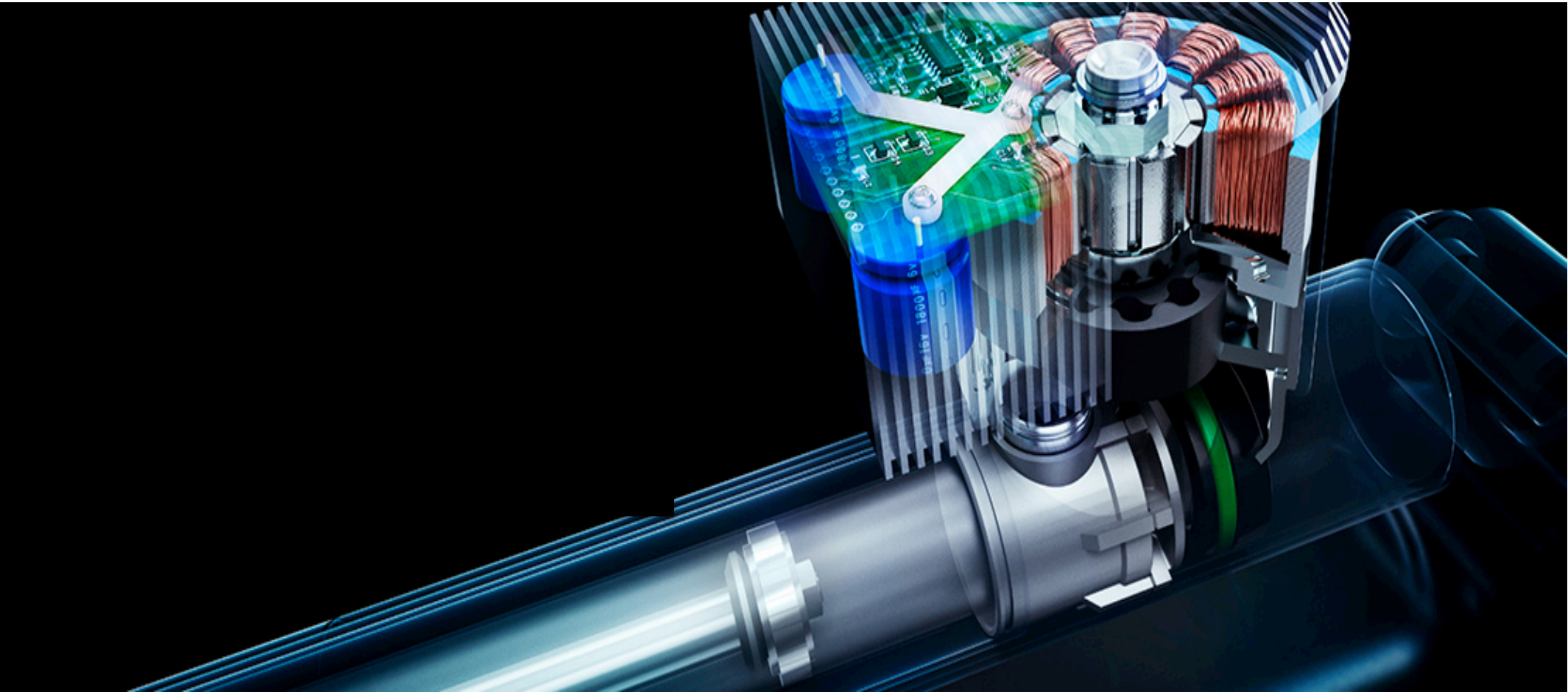


Digital Electrohydraulics, Localized.

This is the game-changing idea that enables us to achieve a
balance of low power, low cost, but excellent performance.



Novel Approach: Local electrohydraulics and controls



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Technical Deep Dive



- System Architecture

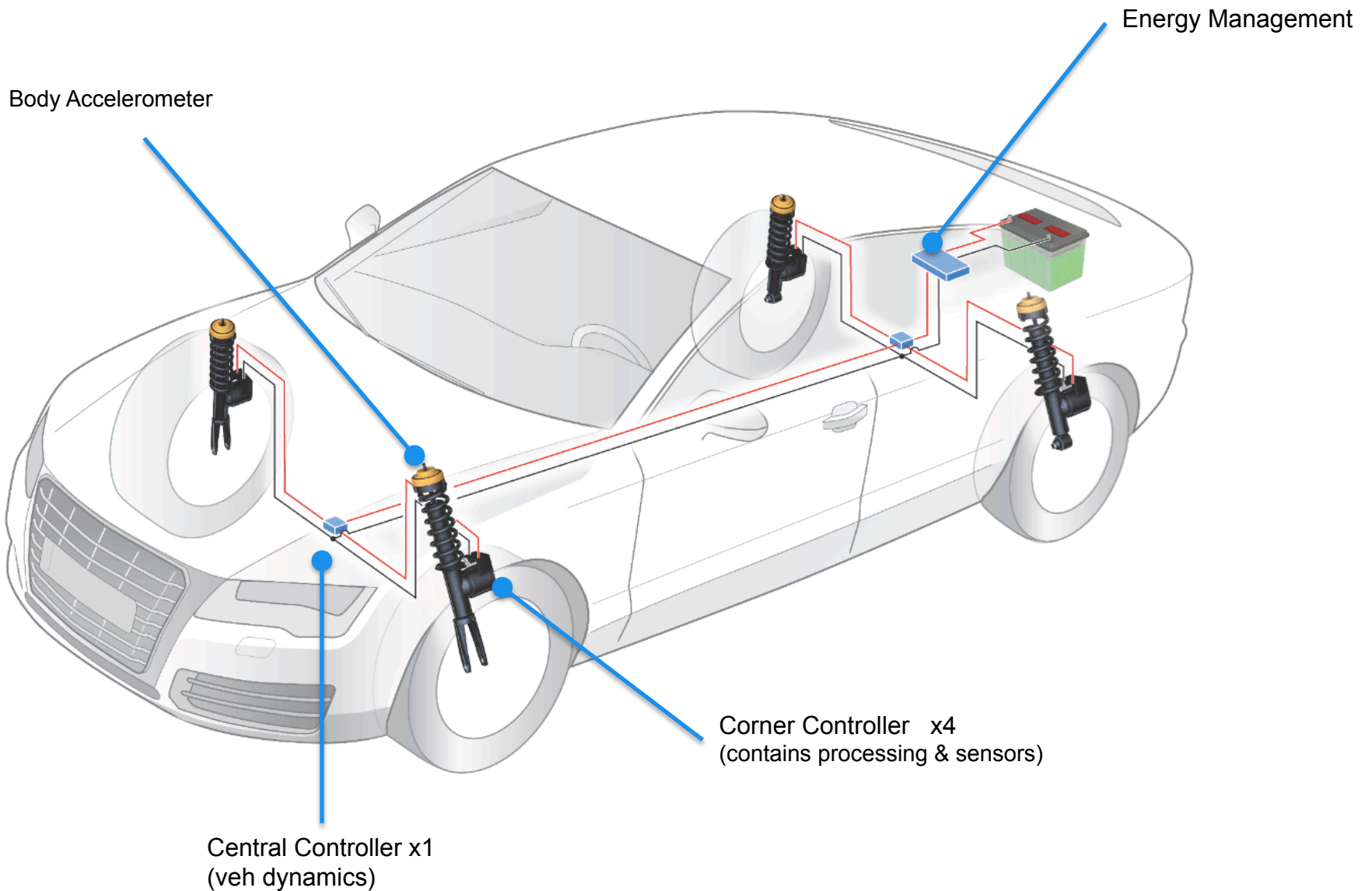
- Deconstruction of a bump

- Control Loop Timing

- Performance & Tuning

- Embedded Software Architecture

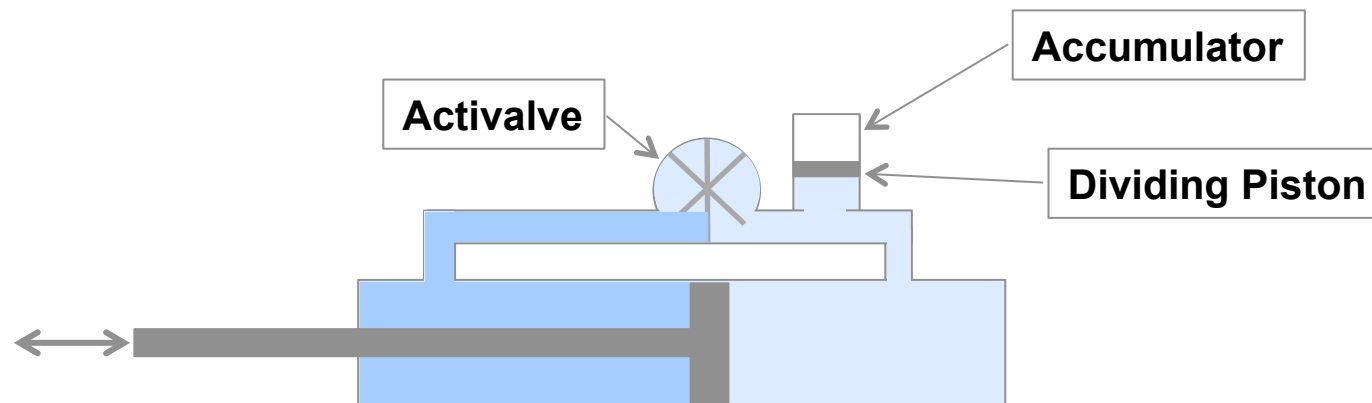
GenShock System Architecture



Hydraulic Principle

Passive Quadrants (I and III)

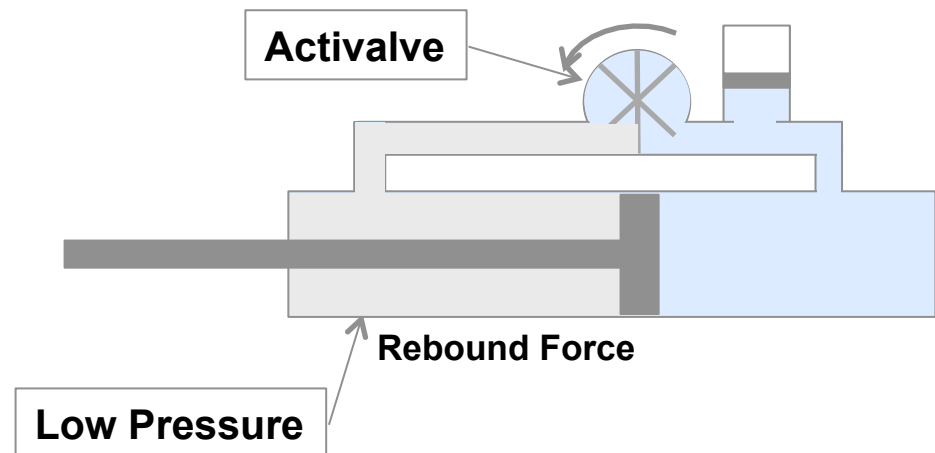
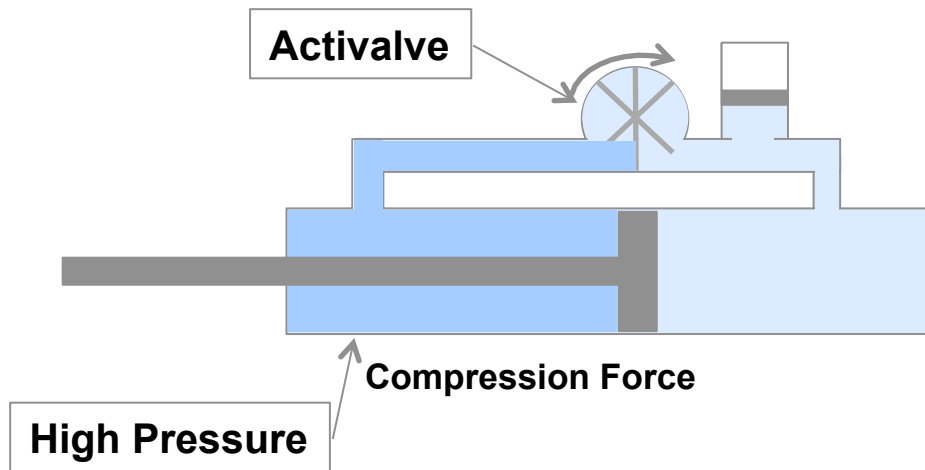
- Oil Flow through the valve in both directions
- Volume of the piston rod is compensated by the gas accumulator
- Gas pressure supports rebound forces
- Hydraulic pump acts like a variable damping valve for oil flow in extension and compression



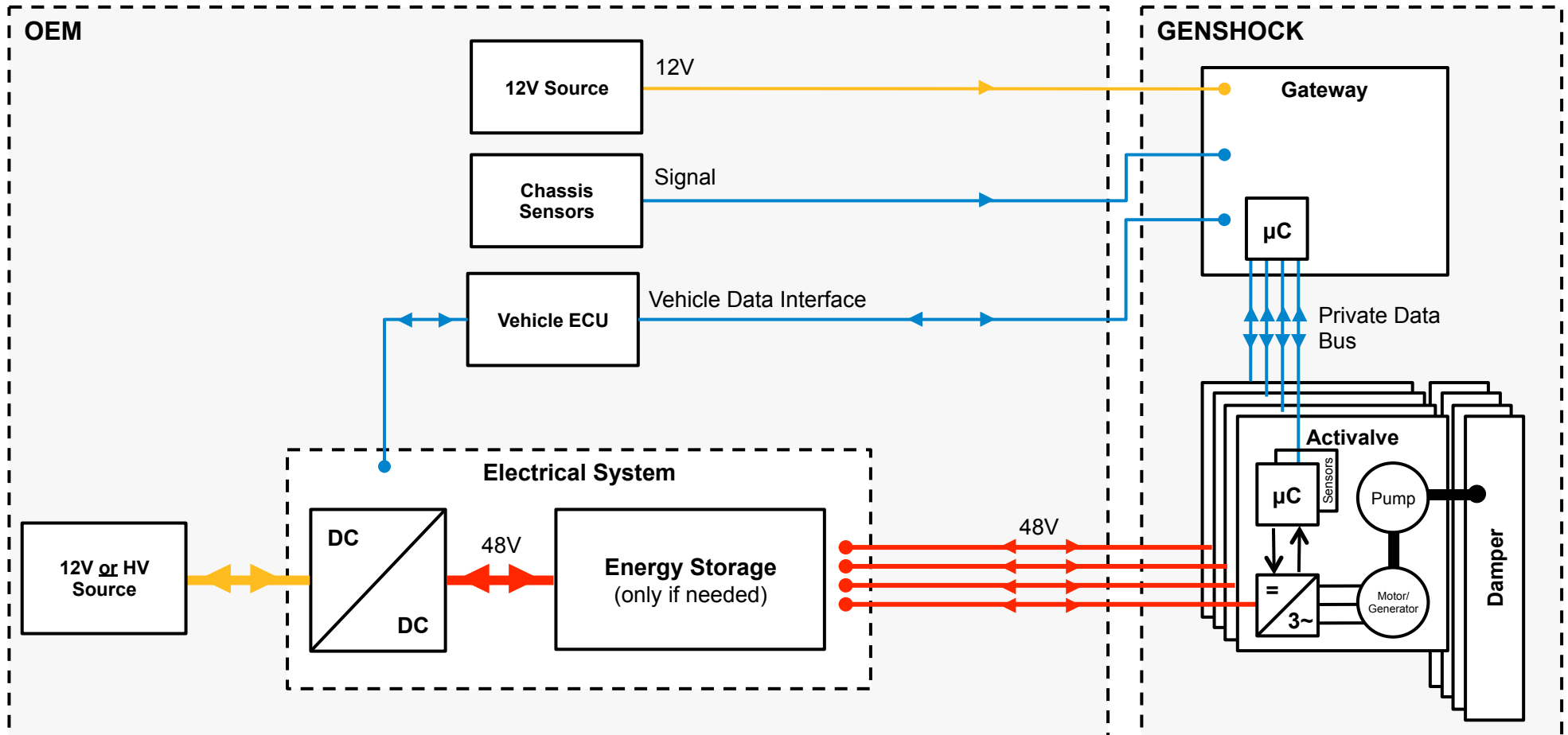
Hydraulic Principle (cont.)

Active Quadrants (II and IV)

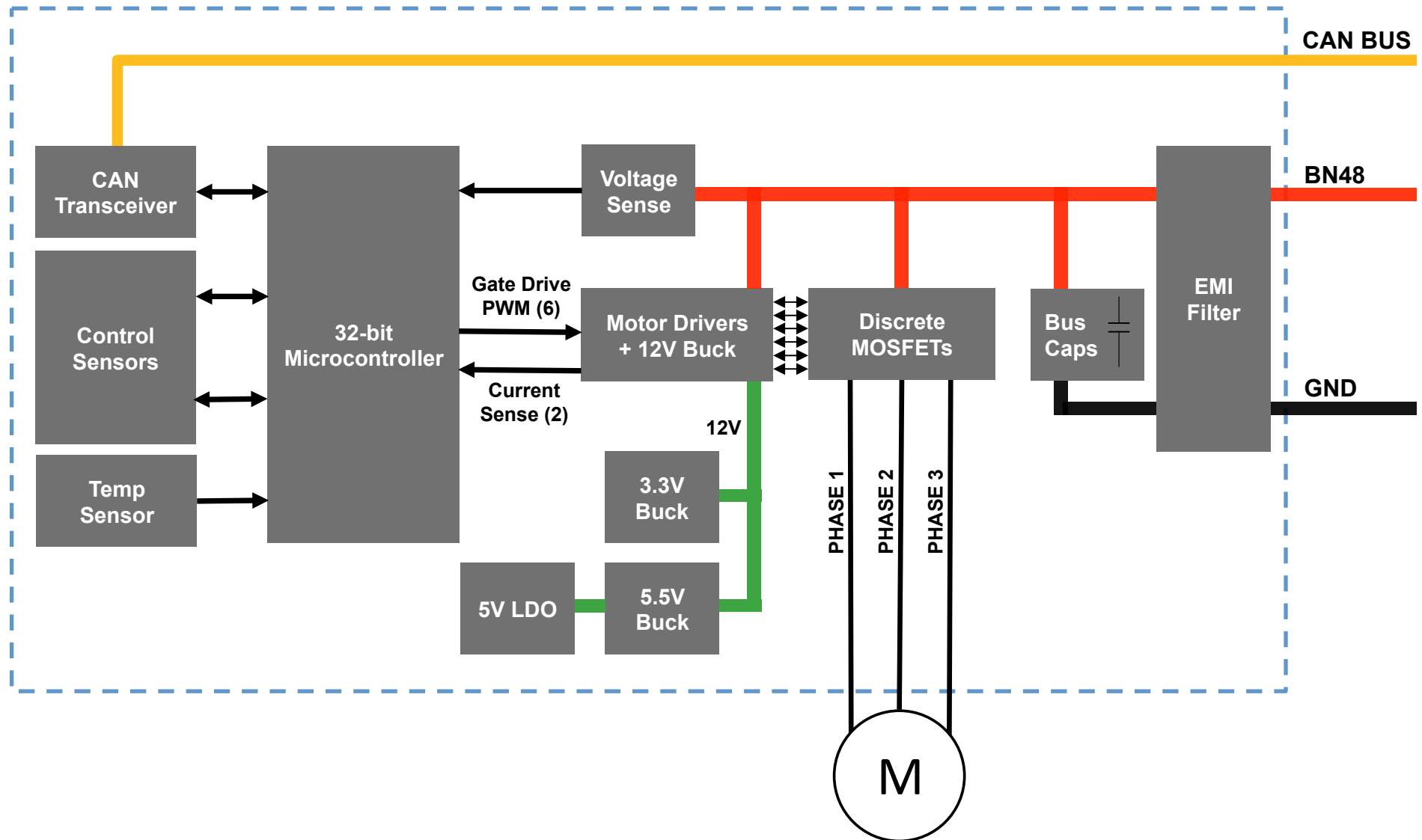
- Activalve is able to supply oil volume independent of the stroke
- Thus, it can increase or decrease pressure acting on the piston



GenShock System Integration



Active Valve Electronics Architecture



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Deconstruction of a bump

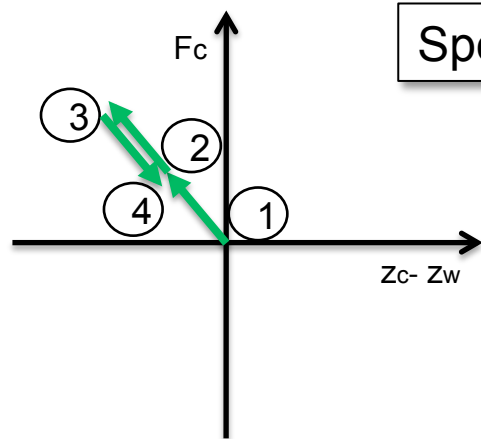
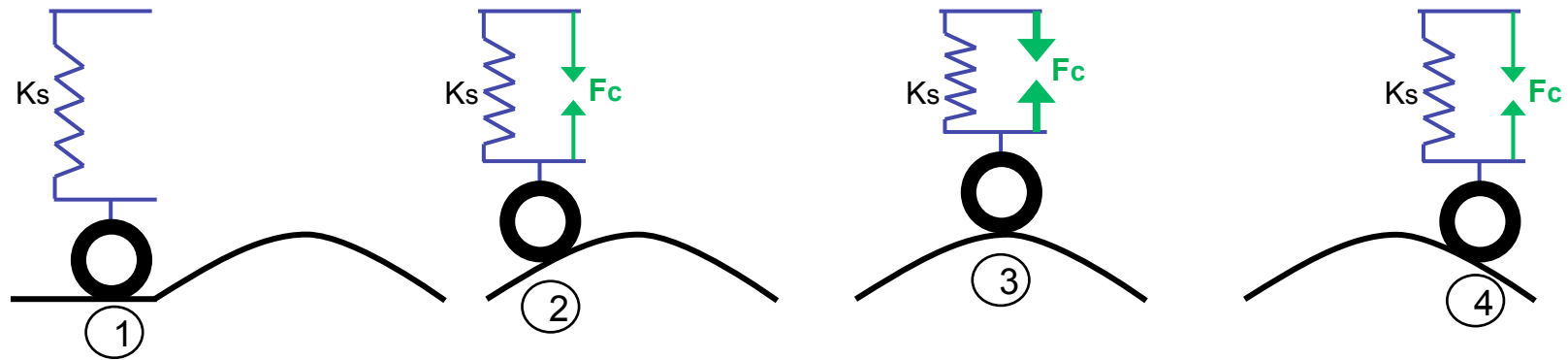
Control Loop Timing

Performance & Tuning

Embedded Software Architecture

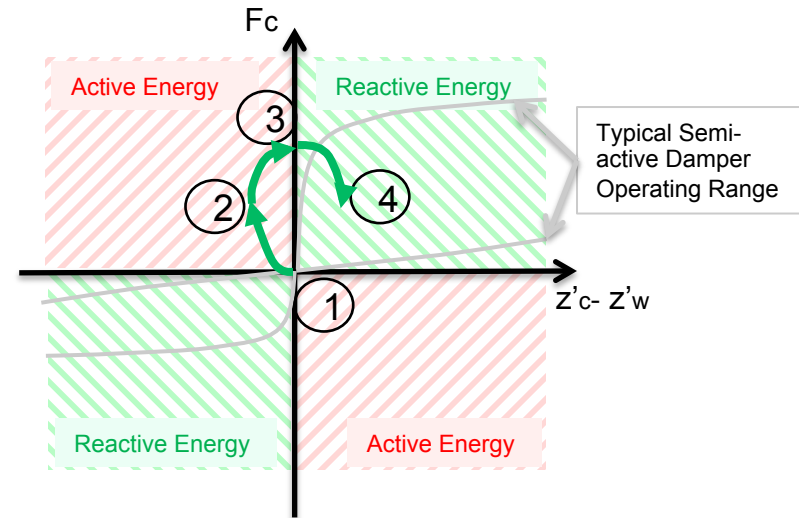
Full active control

Speed bump example



Force vs Position

Speed Bump



Force vs Velocity

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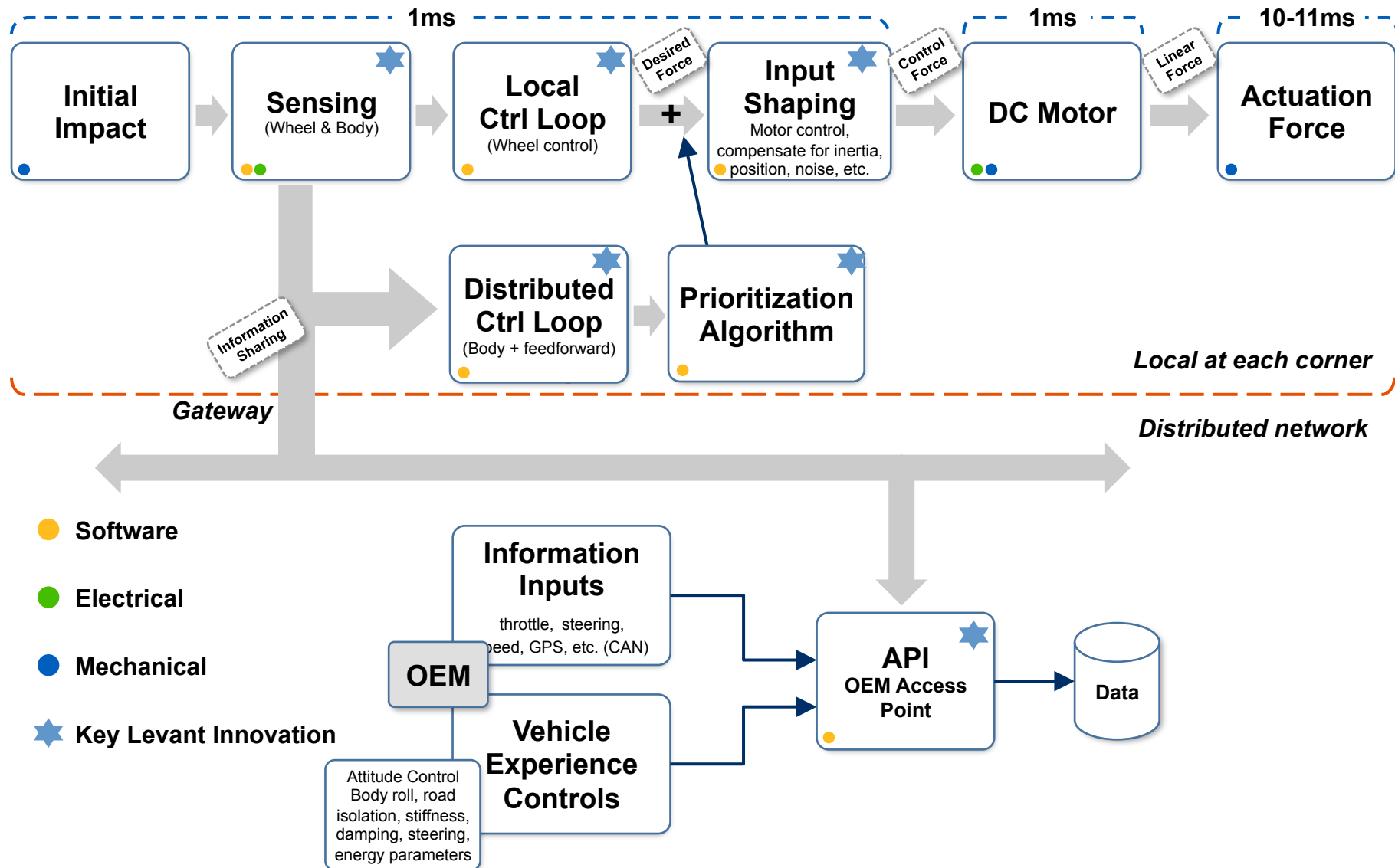


Control Loop Timing

Performance & Tuning

Embedded Software Architecture

GenShock Distributed Control Architecture



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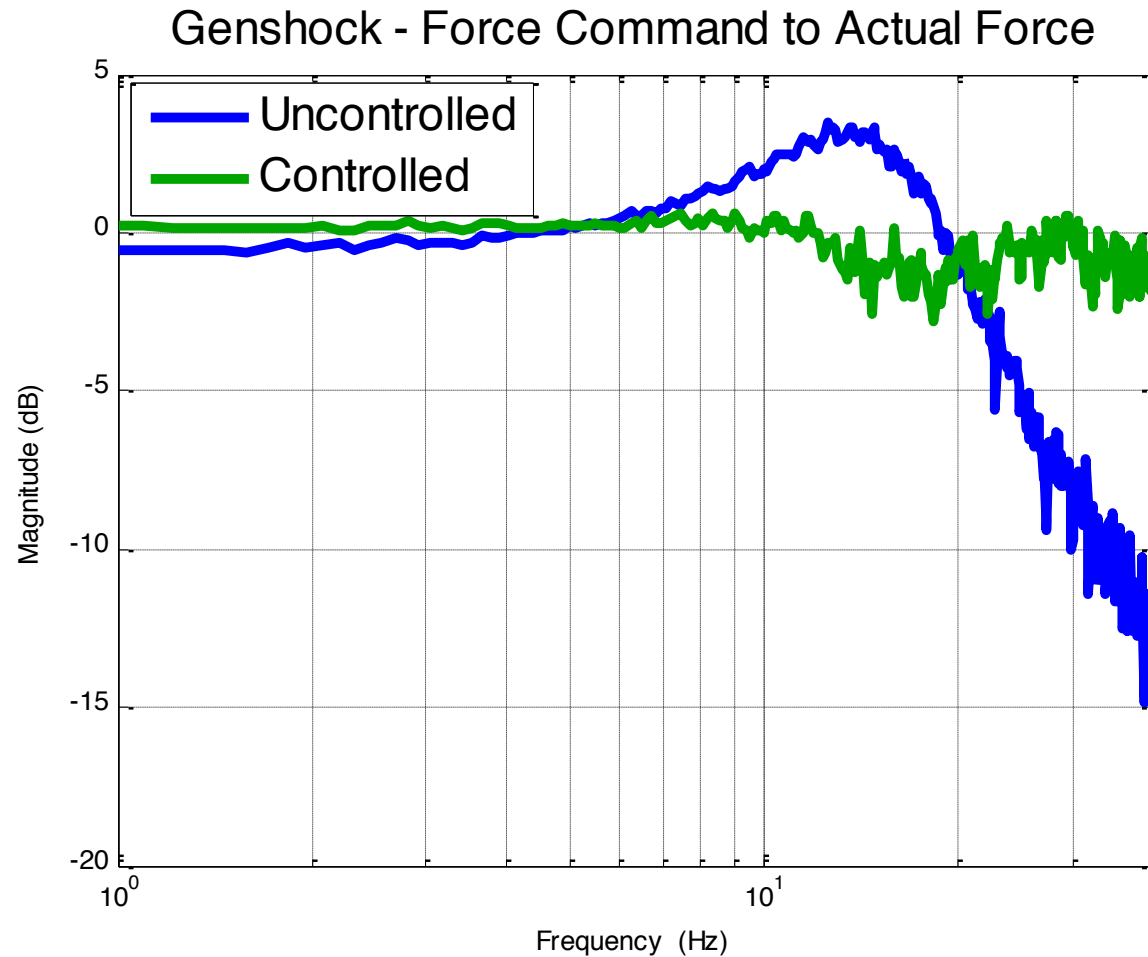
Control Loop Timing



Performance & Tuning

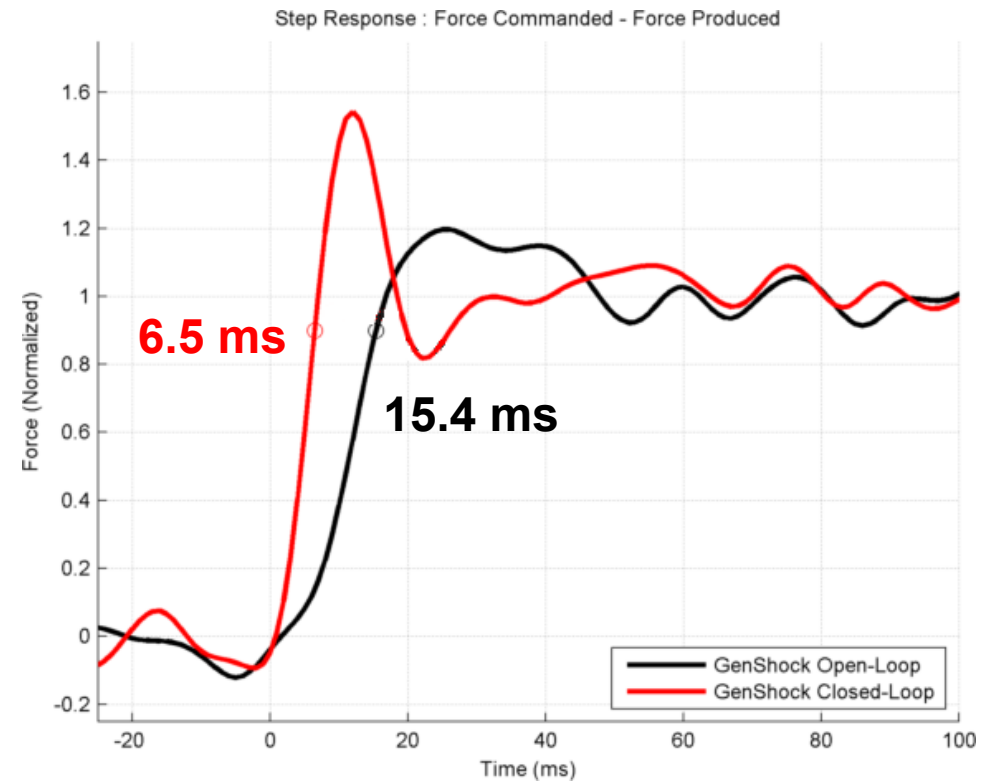
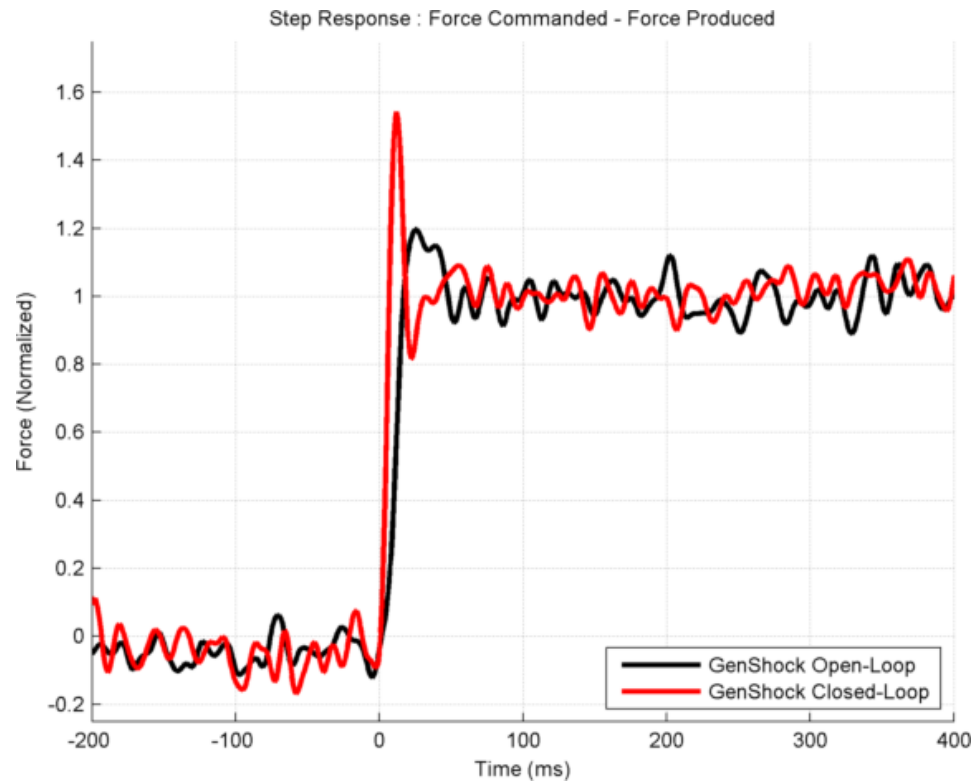
Embedded Software Architecture

Actuator Transfer Function: Command->Actual

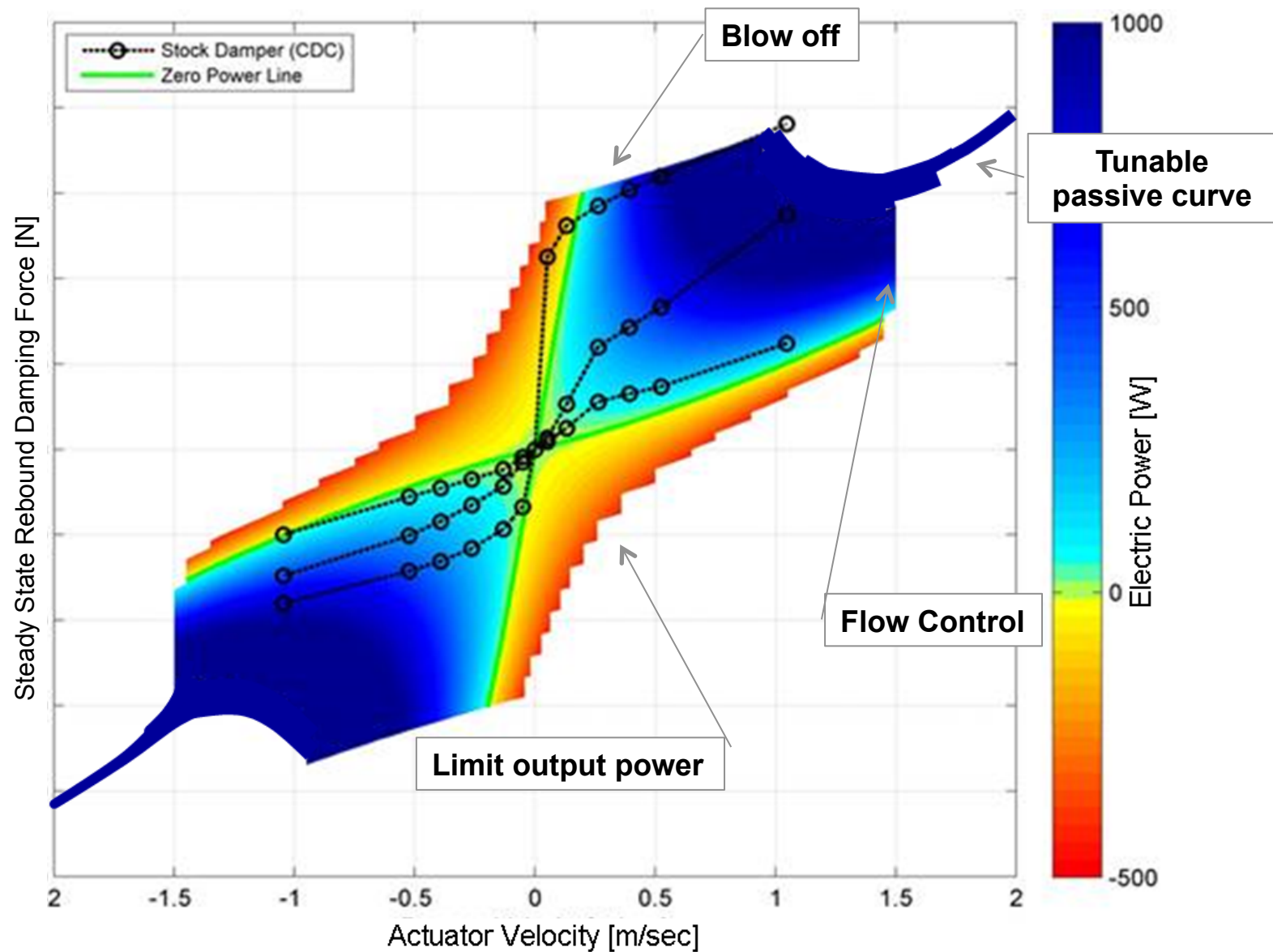


Force transfer function from command to measured output force

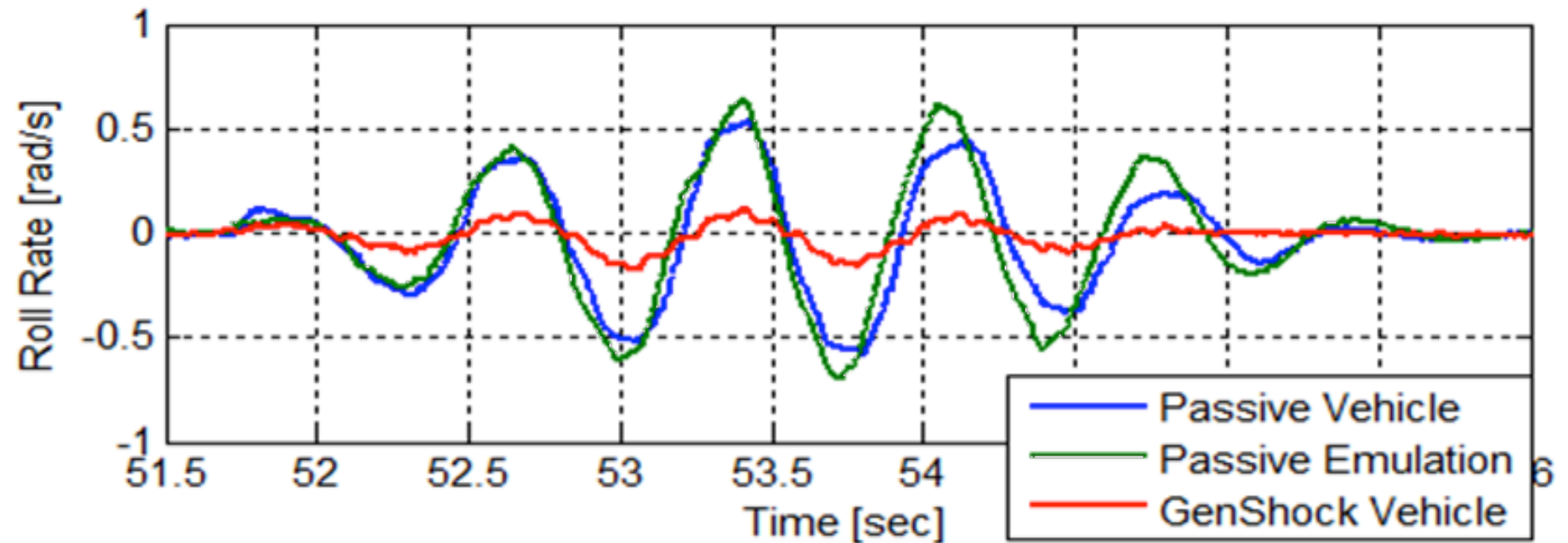
GenShock Actuator Response Time



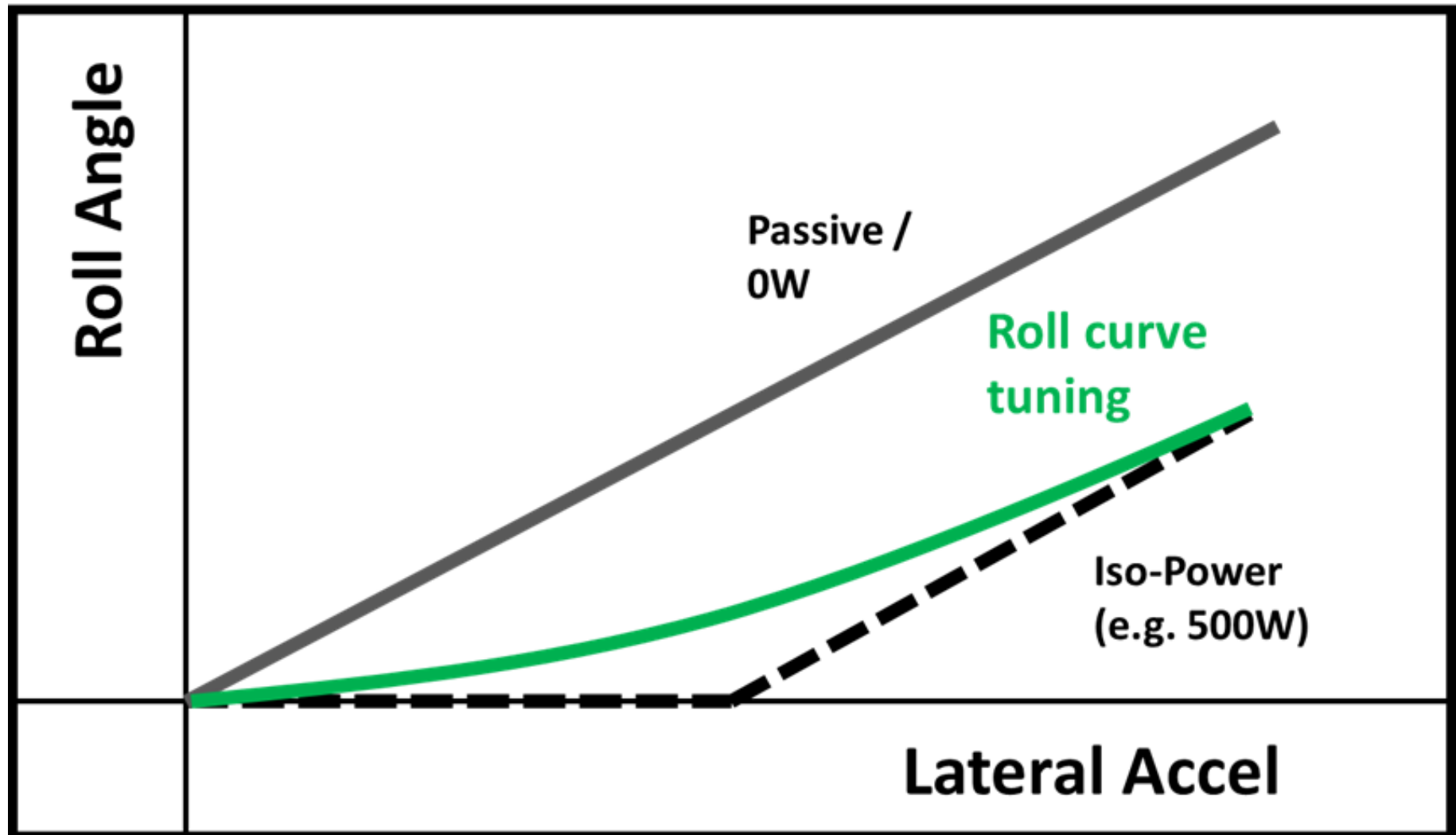
GenShock Actuator Command Authority



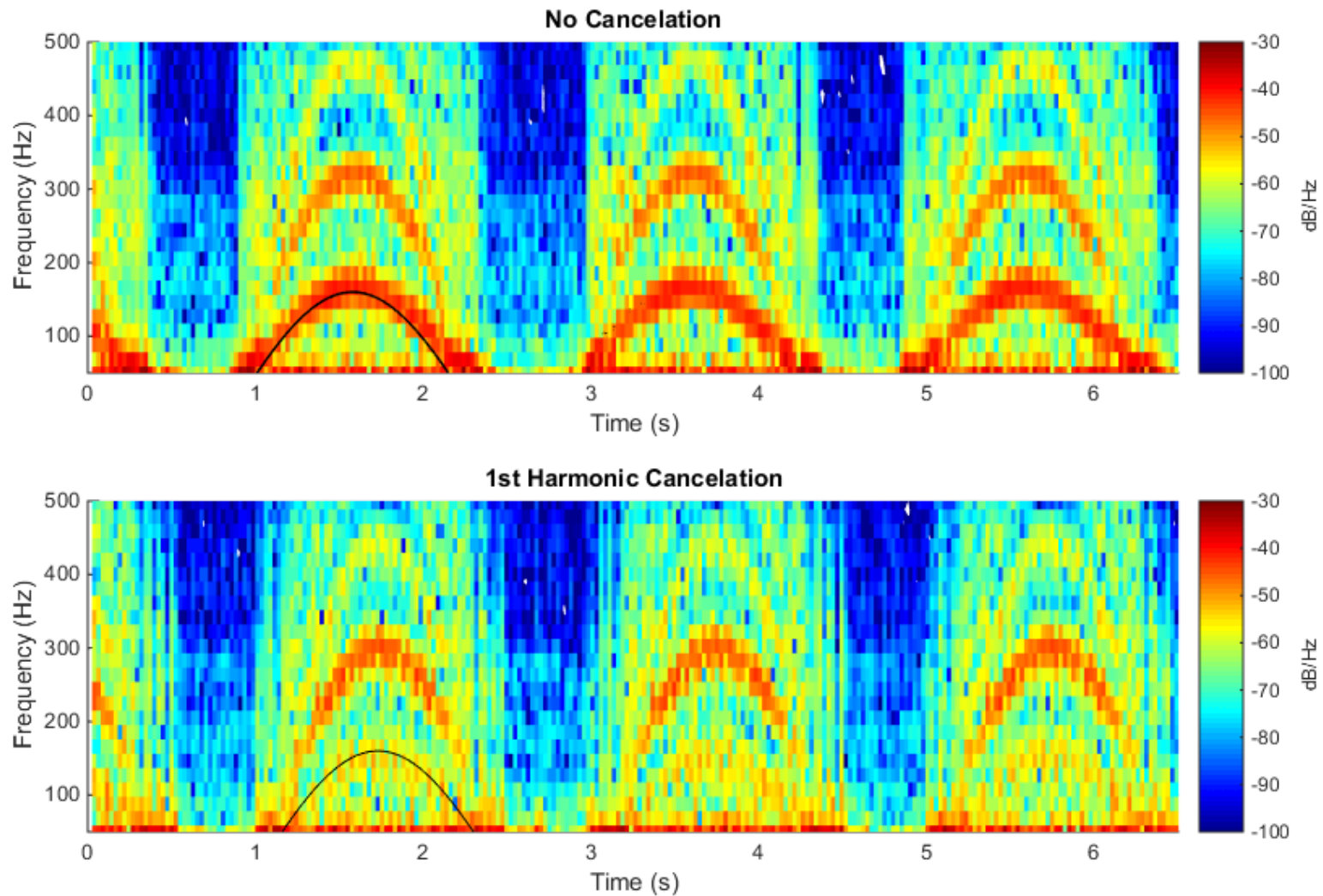
GenShock vs. Passive Roll Rate: Offset Bumps



Roll Curve Tunability & Power Tradeoffs



Noise Cancellation Algorithms



Rod acceleration is reduced dramatically at the 1st harmonic

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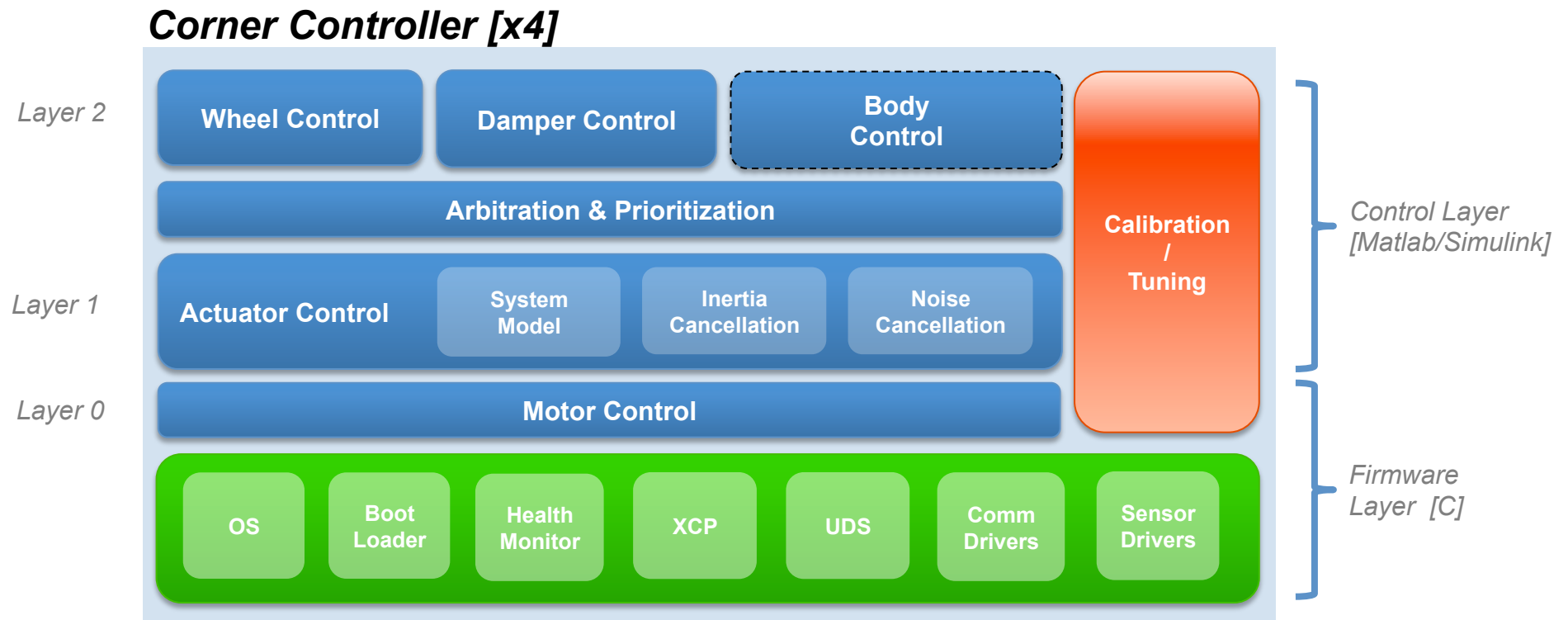
Performance & Tuning



Embedded Software Architecture

GenShock Corner Application Software Architecture

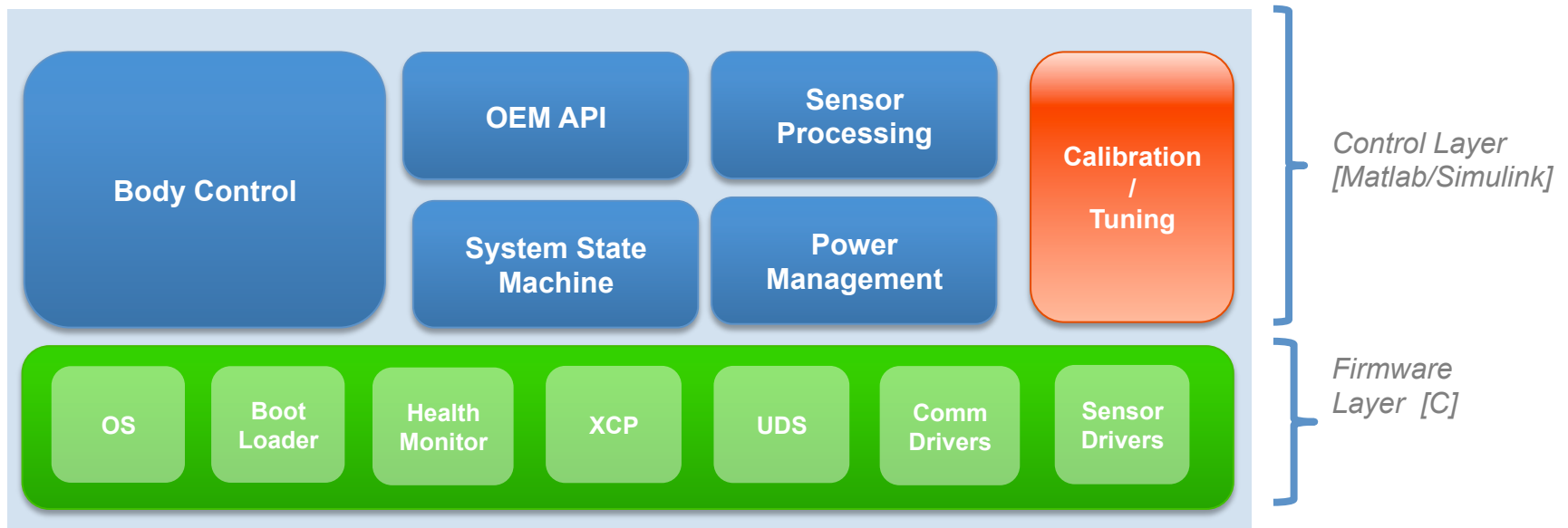
- Bare metal application for increased performance
- Model based design with Matlab/Simulink enables accelerated development
- Control abstraction layers create robust, verifiable design
- Standards based protocol implementations for ease of integration with OEM's



GenShock Central Application Software Architecture

- Coordinated control of vehicle dynamics (cornering, braking, accelerating, etc.)
- System state management (power on/off, fault management, etc.)
- Intelligent power control
- System software update

Central Controller



Thank You.

